International Civil Aviation Organization

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Agenda Item 4: Provision of AOP in the Asia/Pacific Region – Certification and Operations of Aerodromes

SAFETY CONSIDERATIONS AND MITIGATION FOR AIRCRAFT RESCUE AND FIREFIGHTING INVOLVING ADVANCED COMPOSITE MATERIALS

(Presented by HONG KONG, CHINA)

SUMMARY

This paper presents the health and safety risks posed to emergency responders and attending personnel in the event of an aircraft crash and fire incident due to the expanded use of composite materials in modern aircraft design and construction. Aircraft fires involving composite materials may introduce significant hazards including toxic gases, respirable fibres, and adsorbed toxins that can persist beyond the initial firefighting phase. Committed to the highest levels of safety and operational readiness, the Hong Kong Fire Services Department classifies such fires as Hazardous Materials Incidents, establishes hazard control zones, and utilises the Decontamination & Rescue Facility located at Hong Kong International Airport when mass decontamination is required. Other mitigation measures include real-time dust monitoring of fibre dispersion to guide zoning decisions, as well as adapted water application tactics for fibre suppression and thermal cooling during initial response and post-incident recovery.

1. INTRODUCTION

1.1 The aviation industry has witnessed a paradigm shift in aircraft design and construction over the past decades, with modern commercial aircraft increasingly using composite materials. Modern widebody aircraft such as the Airbus A350 and Boeing 787 now have more than 50% of their structural weight made of these advanced materials—a significant increase from the low percentages seen in previous generations. The application of composites has evolved from small components to large primary load-bearing structures.

1.2 This shift is primarily driven by the need for efficiency. Composites are lighter than traditional aluminium, which directly translates into lower fuel consumption and reduced emissions. Their adoption has also enabled new design possibilities, such as large, single-piece composite fuselage barrels, which reduce the number of parts and fasteners required.

1.3 However, the increased use of composite materials—including carbon fibre reinforced polymer and glass fibre reinforced polymer—introduces several key hazards, particularly related to responder safety during crash and fire incidents.

1.4 Recognising these emerging challenges, the Hong Kong Fire Services Department (HKFSD) has proactively implemented a comprehensive suite of measures to mitigate the hazards associated with incidents involving such aircraft. This paper outlines HKFSD's operational response framework, with specific focus on:

(1) the implementation of a Hazardous Materials Incident Protocol;

(2) the utilisation of real-time dust monitors for airborne fibre detection; and

(3) water application tactics.

1.5 HKFSD is dedicated to maintaining the highest levels of safety and operational readiness, ensuring that Hong Kong International Airport (HKIA) remains prepared for the challenges of the modern aviation era.

2. DISCUSSION

Fire and Health Hazards of Composite Materials

2.1 The fire and health hazards associated with composite materials can be categorised into three primary areas: toxic smoke and vapours, respirable fibres, and adsorbed toxins. Each of these hazards presents distinct risks to responders during an aircraft crash and fire incident, and together they create a complex exposure scenario that requires comprehensive protective measures.

2.2 When composite materials are exposed to fire, the polymer resin matrix that binds the fibres begins to decompose and combust. This process releases a range of toxic gases, including carbon monoxide, hydrogen cyanide, and various volatile organic compounds. These combustion products pose an immediate acute health risk to responders, as inhalation can lead to respiratory distress, reduced oxygen delivery to vital organs, neurological impairment, and in high concentrations, loss of consciousness or death. The burning resin matrix also generates dense smoke that can obscure visibility, hampering rescue and firefighting operations while simultaneously exposing responders to a complex mixture of hazardous substances.

2.3 Beyond the gaseous hazards, composite material fires release small airborne fibres. Due to their microscopic diameter—often less than three micrometres—these fibres can be inhaled deep into the lungs, reaching the alveolar region where gas exchange occurs. Once deposited in this sensitive tissue, the rigid fibres can cause mechanical irritation and sustained inflammation. Exposure to fibre fragments can induce inflammatory responses in human lung cells, including accelerated apoptotic cell death.

2.4 A particularly insidious hazard arises from the interaction between the gaseous and particulate hazards described above. Toxic compounds generated during the combustion process—including polyaromatic hydrocarbons and other hazardous chemicals—can adsorb onto the surface of airborne fibres. The fibres thus act as vectors, carrying these toxic substances deep into the respiratory system. This combined mechanical and chemical hazard presents a unique challenge for responder protection, as the fibre-associated toxins may not be effectively filtered by standard respiratory protection designed for gaseous or particulate hazards alone. Furthermore, the adsorbed toxins may elute from the fibres once deposited in lung tissue, creating a sustained local exposure to carcinogenic and otherwise hazardous compounds.

2.5 An additional concern is the persistence of these hazards beyond the active firefighting phase. Most composite material decomposition occurs during the smouldering phase of combustion, which can persist for several days after visible flames have been extinguished. This means that fibre release and toxic gas emissions may continue throughout the post-fire recovery and investigation period.

Mitigation Measure (1) - Hazardous Materials Incident Protocol

2.6 In view of the hazards described above, when an aircraft constructed with composite materials is involved in a fire, HKFSD may, depending on the severity of the incident, classify it as a Hazardous Materials Incident and implements the corresponding handling procedures. As presented at the Ninth Meeting of this Sub-Group (AOP/SG/9) in 2025, HKFSD introduced the world's first Decontamination and Rescue Facility for handling hazardous materials incidents at HKIA. The facility may also be utilised for mass decontamination of responders, flight crew and passengers in such incidents.

2.7 Hazard control zones are established in three categories—the Hot Zone, the Warm Zone, and the Cold Zone—to ensure responder safety.

(a) Hot Zone – The Hot Zone immediately surrounds the aircraft and extends far enough to prevent personnel outside the zone from being adversely affected by hazardous materials releases. This zone is restricted to trained personnel wearing appropriate personal protective equipment.

(b) Warm Zone – The Warm Zone is the control zone at a hazardous materials incident site where personnel and equipment decontamination, as well as Hot Zone support, takes place.

(c) Cold Zone – The Cold Zone serves as a support zone where manpower, equipment, and appliances are situated.

Mitigation Measure (2) – Dust Monitoring

2.8 Dust monitoring serves a critical function by providing real-time, objective data on particulate concentrations, enabling incident commanders to make evidence-based decisions regarding responder protection, cordon boundaries, and decontamination requirements. The Airport Division of HKFSD is equipped with dedicated dust monitors capable of detecting respirable fibrous particles.

2.9 Dust monitors deployed at downwind cordon boundaries serve a critical safety function by detecting fibre dispersion beyond the Hot Zone. The concentration data collected support decisions regarding:

(a) whether the Hot Zone requires an extension downwind;

(b) whether downwind evacuation of unprotected personnel or the public is necessary; and

(c) the effectiveness of fibre suppression measures such as water spraying.

Mitigation Measure (3) – Water Application Tactics

2.10 During the active fire phase, the primary goals are fire knockdown and fuselage protection, but tactics must be adapted to avoid creating additional airborne hazards. A high-pressure jet tends to shatter charred composite material surfaces, generating a cloud of sharp, respirable dust, whereas a low-pressure spray binds the particles to the water. Once the visible flame is knocked down, firefighters are trained to transition to the application of a "softening" spray rather than a solid jet.

2.11 Composite materials can reignite or continue off-gassing until they cool below a threshold of approximately 150°C. Thermal imaging cameras are used to guide water application, ensuring that the composite material surface is cooled to ambient temperature, rather than only until the fire is extinguished.

2.12 Post-incident operations represent the highest risk for secondary dust exposure, as the structural integrity of the materials is lost and dry surfaces are disturbed. Dry composite dust that has settled on the ground can easily become re-suspended by wind, vehicle movement, or personnel activity. Continuous wetting suppresses this hazard by immobilising the fibres. The Airport Division of HKFSD assists by applying fine water sprays to ensure that the wreckage remains wetted at all times during recovery operations.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) recognise the elevated health and safety risks posed by composite materials in modern aircraft construction in the event of aircraft fire incidents, and note the mitigations implemented by HKFSD; and

b) discuss any relevant matters as appropriate.

— END —

Safety Consideration and Mitigation for Aircraft Rescue and Firefighting Involving Advanced Composite Materials

Airport Division
Hong Kong Fire Services Department

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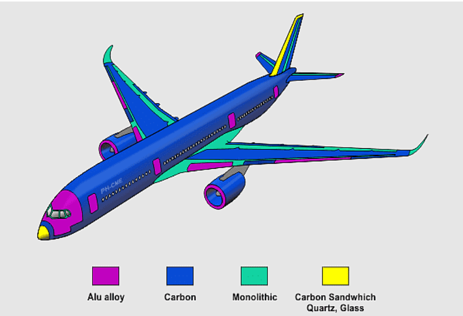
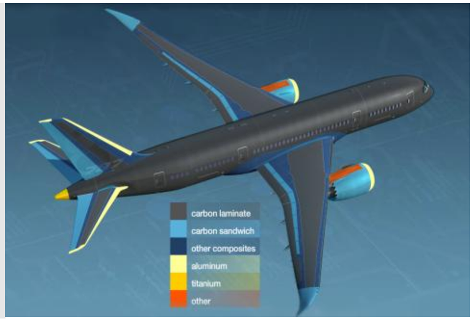
Modern commercial aircraft structures are now majority composite





Modern aircraft examples

Airbus A350, Boeing B787

Structural weight in composites

more than 50%

Evolution

From small components → To large primary load-bearing structures

Key drivers

- Lighter weight
- Reduced emissions
- Lower fuel consumption
- New design possibilities (single-piece fuselage barrels)

Three hazard categories define the operational risk profile

Toxic smoke/vapours

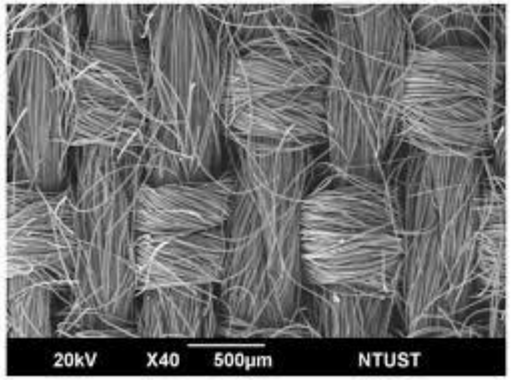
- Toxic gases released: carbon monoxide, hydrogen cyanide, volatile organic compounds

Respirable fibres

- Fibres less than 3 micrometres reach alveolar region
- Can cause inflammation

Adsorbed toxins

- Toxic compounds (PAHs) adsorb onto fibre surfaces
- Act as vectors into the respiratory system



Smouldering and residual contamination can persist after flame knockdown

Flames extinguished → Smouldering for several days

Persistence issue

- Smouldering phase can last several days after flames extinguished

Operational implication

- Ongoing risk of toxic smoke/vapours
- Ongoing risk of respirable fibres
- Ongoing risk of adsorbed toxins

Mitigation 1: Implementation of Hazardous Materials Incident Protocol

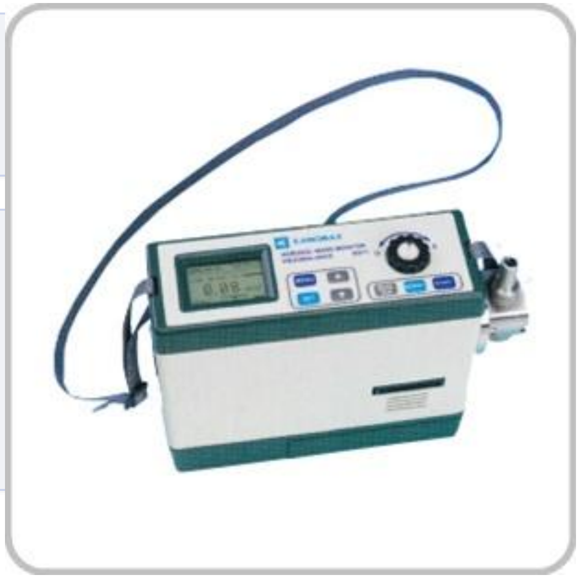
- World's first Decontamination and Rescue Facility at HKIA (introduced 2025)
  Will be utilized for mass decontamination of responder, flight crews and passengers

Hot Zone	Immediate aircraft vicinity; restricted to trained personnel with PPE
Warm Zone	Decontamination and Hot Zone support
Cold Zone	Support zone for manpower, equipment, appliances

Mitigation 2:
Real-time Dust Monitoring

- Real-time particulate concentration data supports decisions

Capability	Airport Division equipped with dust monitors for respirable fibrous particles
Application	Downwind cordon boundary monitoring
Decisions	Hot Zone extension decisions Downwind evacuation needs Fibre suppression effectiveness



Mitigation 3: Water Application Tactics

- Active fire → Avoid high-pressure → Low-pressure binding spray → Softening spray → TIC cooling to <150°C → Continuous wetting

Active Fire Phase	Fire knockdown and fuselage protection Avoid: High-pressure jets (shatter charred composites, create respirable dust) Use: Low-pressure spray to bind particles
After Knockdown	Transition to “softening” spray Cool to ambient temperature (below 150°C threshold)
Post-Incident	Continuous wetting during recovery operations to prevent dust re-suspension

Core Conclusion:
Composites Change Aircraft Fire Hazards; Responds with Protocol, Monitoring, and Water Tactics

Key hazards introduced

- Toxic smoke/vapours
- Respirable fibres
- Adsorbed toxins

HKFSD proactive measures

1. Hazardous Materials Incident Protocol
2. Real-time dust monitors
3. Water application tactics

Thank You

Questions & Discussion